

# FROM SIR-C TO SRTM

Yunjin Kim

Jet Propulsion Laboratory

California Institute of Technology

4800 Oak Grove Drive

Pasadena, CA 91109

[ykim@radar-sci.jpl.nasa.gov](mailto:ykim@radar-sci.jpl.nasa.gov)

# SIR-C/X-SAR Mission

- Joint U.S./German/Italian project
- Two successful flights in 1994 (STS-59 in April and STS-68 in October) on space shuttle Endeavour
- For the two flights, 143 hours of SAR data were recorded.
- Data takes were largely over pre-selected experimental sites.
- Two flights to assess change with time due to seasons and other factors
- Last three days of the second flight for repeat-track interferometry (baseline separation 10 - 4700 m)
- SIR-C/X-SAR demonstrated dramatic new capabilities only possible with a multi-parameter imaging radar.

# SIR-C/X-SAR Instrument Characteristics

Parameter	SIR-C (L-band)	SIR-C (C-band)	X-SAR
Frequency (MHz)	1250	5300	9600
Bandwidth (MHz)	10, 20, and 40	10, 20, and 40	10 and 20
Altitude (km)	225	225	225
Polarization	Quad-polarization	Quad-polarization	Vertical
Pulse Length ( $\mu$ sec)	8.5, 17, and 34	8.5, 17, and 34	40
Peak Power (W)	4000	1200	3300
Antenna Width (m)	2.9	0.74	0.4
Antenna Length (m)	12	12	12
Swath Width (km)	From 15 to 80	From 15 to 80	From 15 to 80
Look Angle (degrees)	From 20 to 60	From 20 to 60	From 20 to 60

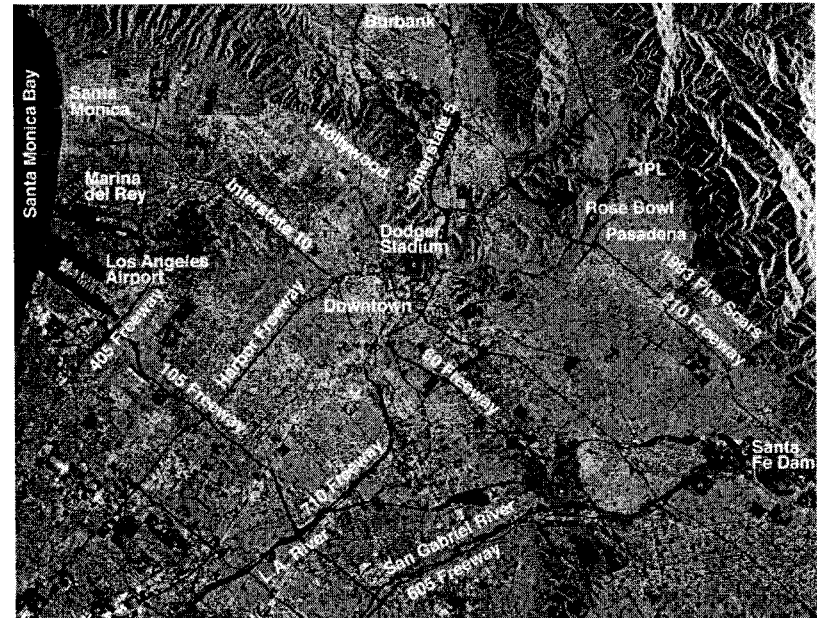
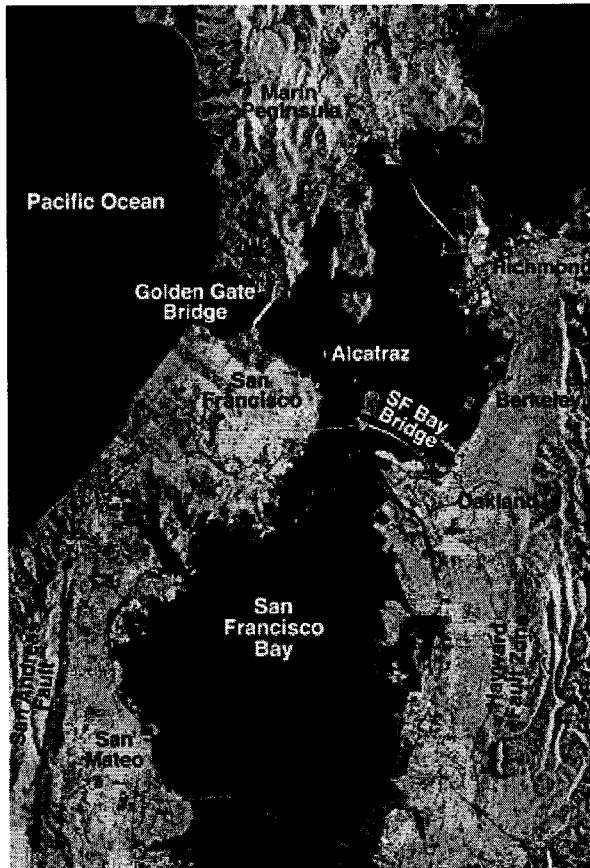
- SIR-C phased array antenna to enable beam steering and spoiling
  - ScanSAR
  - Spotlight
- SIR-C/X-SAR weighed approximately 20,000 pounds and used up to 9 kW shuttle power

# Sudan Collision Zone



- Keraf Suture zone (northern Sudan)
  - The area between the fault and the Nile is part of the collision zone where the ancient continents of East and West Gondwana crashed into each other to form the super-continent Greater Gondwana more than 600 million years ago
- 18 km x 20 km
- R:  $L_{vv}$ , G:  $L_{vh}$ , B:  $C_{vh}$

# San Francisco & Los Angeles



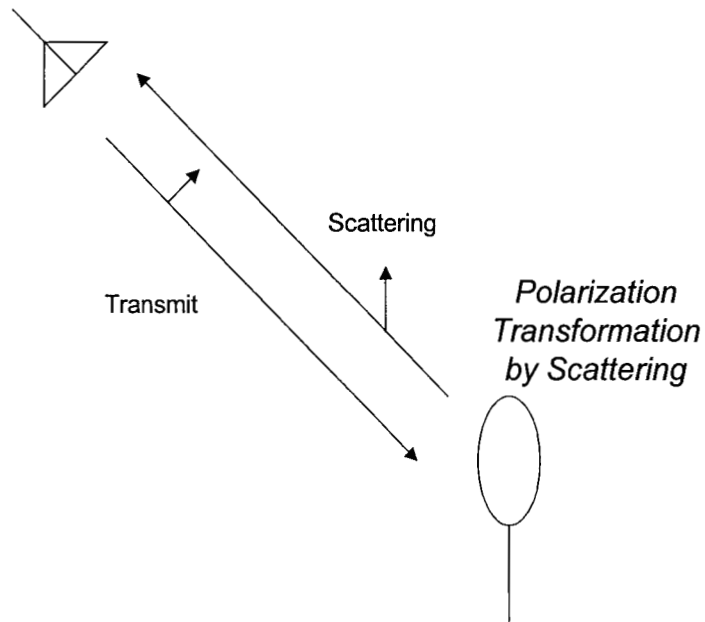
# Central Africa

Lake Kivu



- Gorilla habitat
  - endangered mountain gorilla
  - bamboo forest
- Virunga volcano chain along the border of Rwanda, Zaire, and Uganda
- Nyiragongo volcano (3465 m)
- Acquired on October 3, 1994

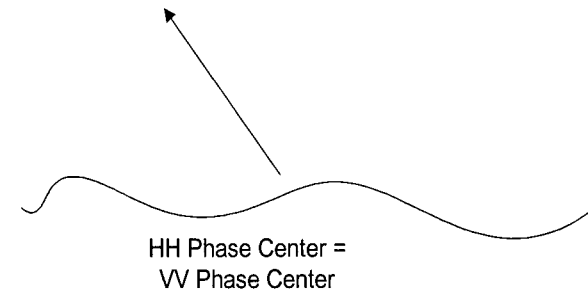
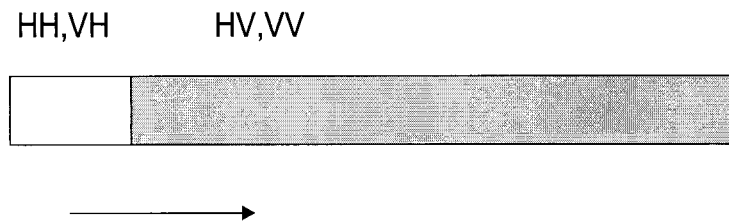
# Polarimetry Fundamentals



- Scattering objects as polarization transformer
- Applications
  - Inversion of scattering matrix for geophysical parameters

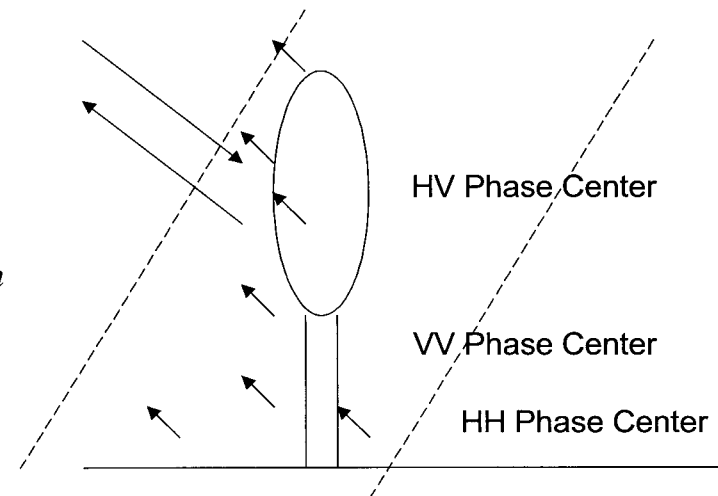
$$\begin{bmatrix} r_h \\ r_v \end{bmatrix} = \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix} \begin{bmatrix} t_h \\ t_v \end{bmatrix}$$

# SAR Polarimetry



$$\begin{bmatrix} S_{hh} \\ S_{hv} \\ S_{vh} \\ S_{vv} \end{bmatrix}$$

Backscattering :  $s_{hv} = s_{vh}$



# Polarimetric Data Correlation

- Coherent scattering vector

$$\vec{k}_L = \begin{bmatrix} S_{hh} \\ \sqrt{2}S_{hv} \\ S_{vv} \end{bmatrix}$$




- Polarimetric data correlation

	$S_{hh}^*$	$S_{hv}^*$	$S_{vv}^*$
$S_{hh}$	$\langle S_{hh} S_{hh}^* \rangle$	$\frac{\langle S_{hh} S_{hv}^* \rangle}{\sqrt{\langle S_{hh} S_{hh}^* \rangle \langle S_{hv} S_{hv}^* \rangle}}$	$\frac{\langle S_{hh} S_{vv}^* \rangle}{\sqrt{\langle S_{hh} S_{hh}^* \rangle \langle S_{vv} S_{vv}^* \rangle}}$
$S_{hv}$	Complex Conjugate	$\langle S_{hv} S_{hv}^* \rangle$	$\frac{\langle S_{hv} S_{vv}^* \rangle}{\sqrt{\langle S_{hv} S_{hv}^* \rangle \langle S_{vv} S_{vv}^* \rangle}}$
$S_{vv}$	Complex Conjugate	Complex Conjugate	$\langle S_{vv} S_{vv}^* \rangle$

# Inundation map derived from SIR-C data









SIR-C IMAGE

	LHH
	LHV
	LWV INVERTED



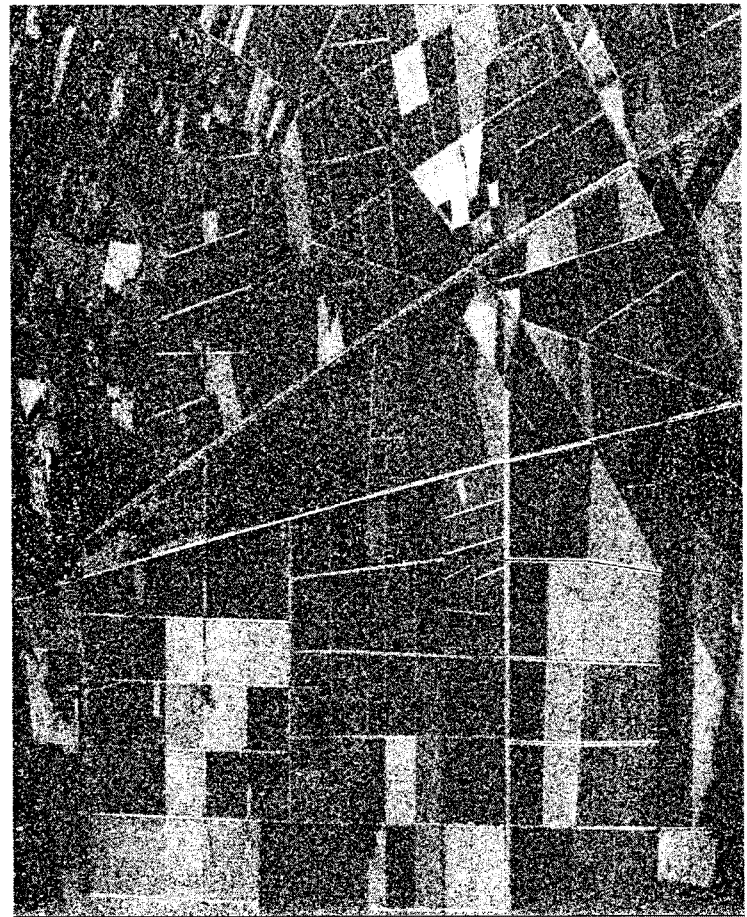
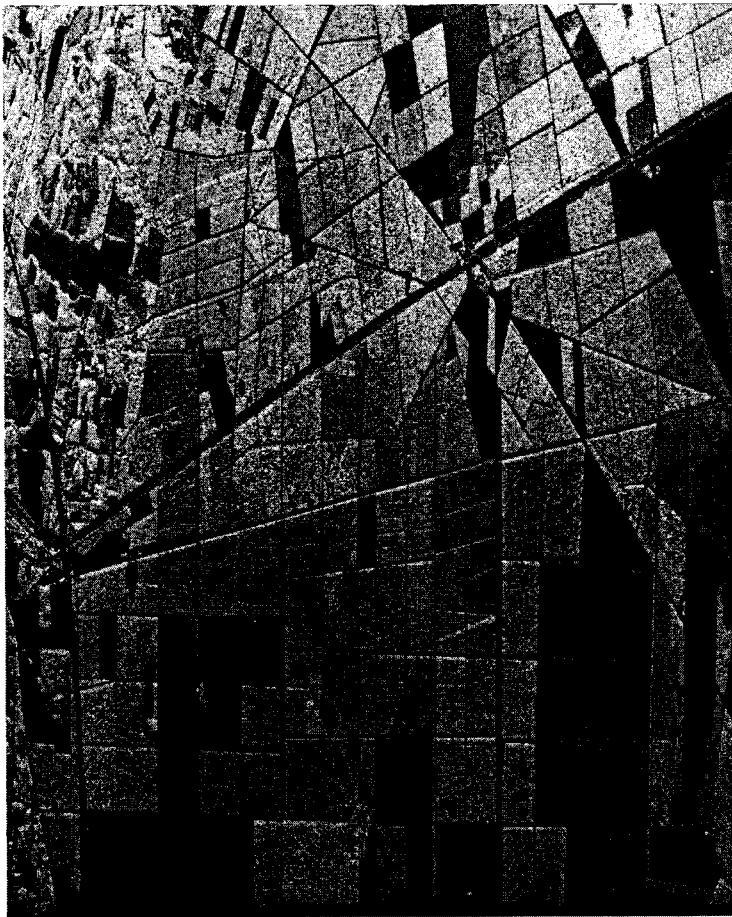
INUNDATION MAP

	FLOODED FOREST		UNFLOODED FIELDS
	UNFLOODED FOREST		FLOODED SHRUBS
	OPEN WATER		FLOATING/FLOODED GRASSES

- Use L-band HH, HV, and VV
- SRL-1 mission
- Rio Solimoes River in Brazil

From *Operational Use of Civil Space-Based SAR* prepared by Interagency Ad Hoc Working Group on SAR, July 1996

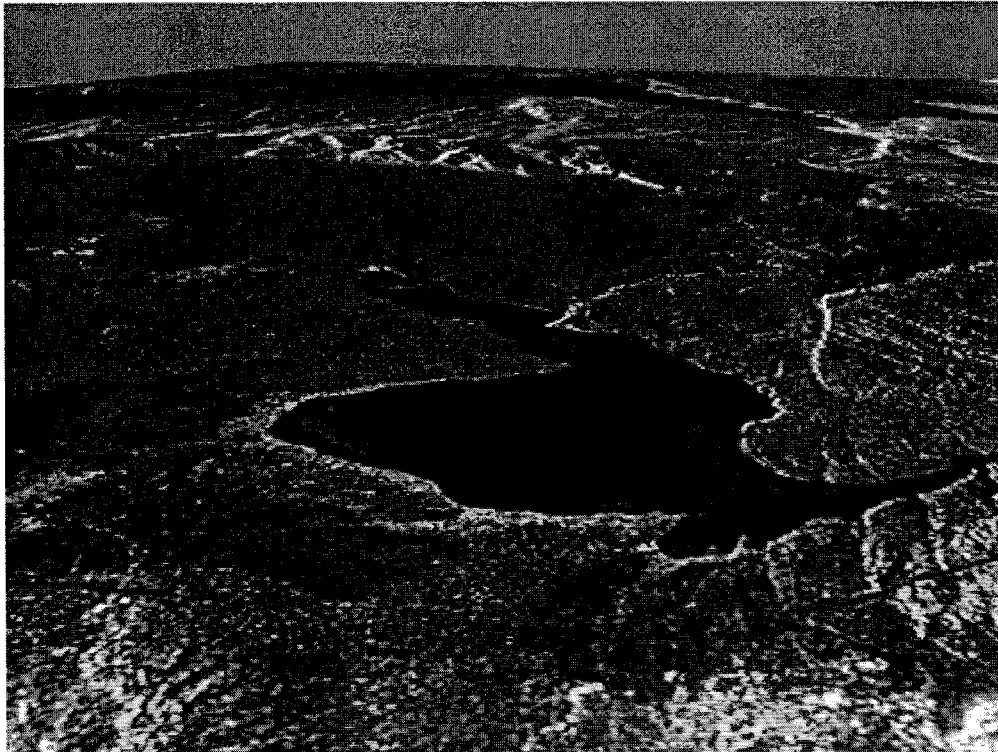
# SOUTH FEN (AIRSAR L-band)



R:HH G:HV B:VV

$$\frac{\langle S_{hh} S_{vv}^* \rangle}{\sqrt{\langle S_{hh} S_{hh}^* \rangle \langle S_{vv} S_{vv}^* \rangle}}$$

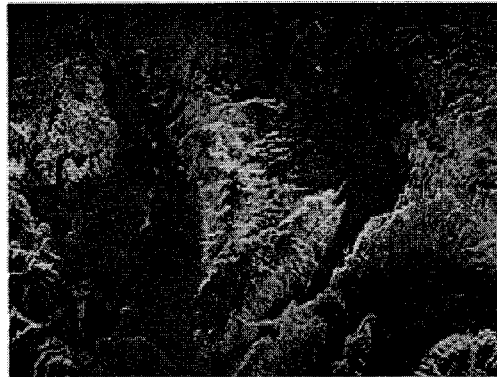
# SIR-C Repeat Track Interferometry (Long Valley)



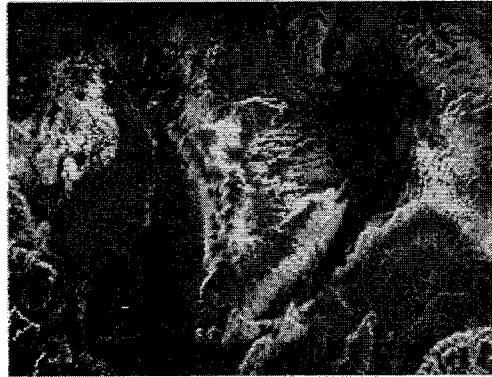
- Interferometry
  - April 13, 1994
  - October 3, 1994

# Radar Interferometry (Long Valley)

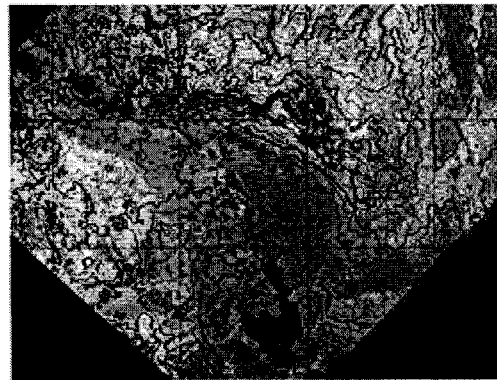
$L_{hh}$



Interferogram



Topographic  
Map



3-D



# Polarimetric Interferometry Data Correlation

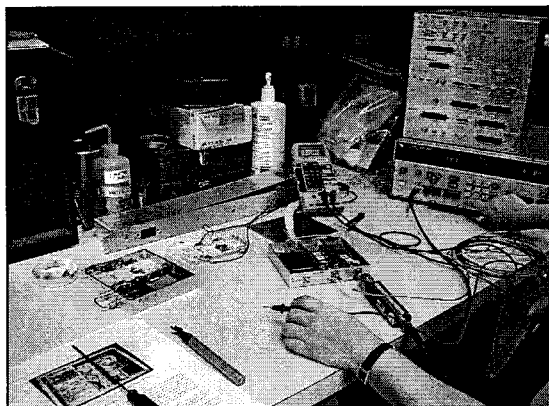
	$S_{hh}^{(u)*}$	$S_{hv}^{(u)*}$	$S_{vv}^{(u)*}$	$S_{hh}^{(l)*}$	$S_{hv}^{(l)*}$	$S_{vv}^{(l)*}$
$S_{hh}^{(u)}$	<b>Upper Antenna Polarimetry</b>			HH interf.	HPI	HPI
$S_{hv}^{(u)}$				HPI	HV interf.	HPI
$S_{vv}^{(u)}$				HPI	HPI	VV interf.
$S_{hh}^{(l)}$	<b>Complex conjugate of the upper right matrix</b>			<b>Lower Antenna Polarimetry</b>		
$S_{hv}^{(l)}$						
$S_{vv}^{(l)}$						

Note: HPI stands for Hybrid Polarization Interferometry.

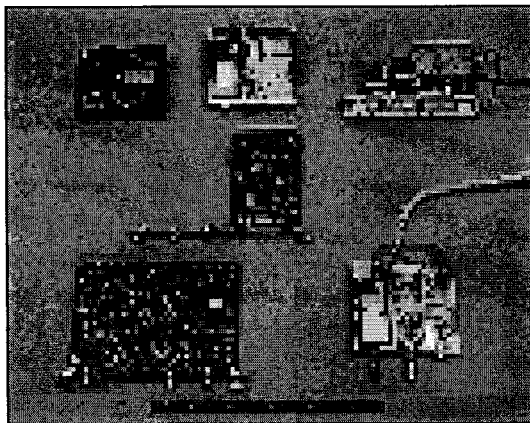
# Multi-parameter SAR Data Applications

- Multi-parameter: L-band polarimetric, C-band polarimetric, and X-band VV SAR data
- Applications
  - Repeat track interferometry
    - DEM (Digital Elevation Map)
    - Surface change detection
    - Polarimetric interferometry
  - Biomass
  - Soil moisture
  - Land cover classification
  - Sea ice classification
  - Inundation map

# Radar Technology Infusion



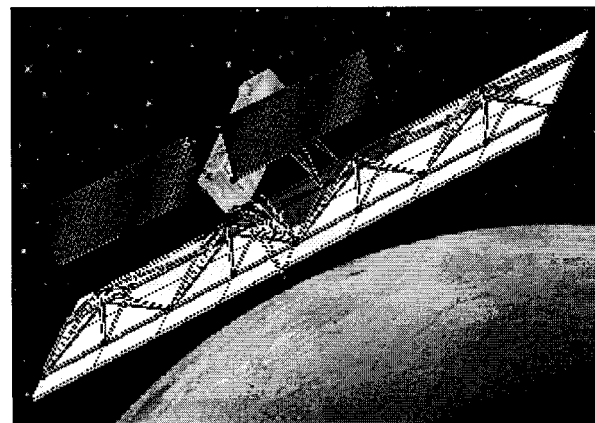
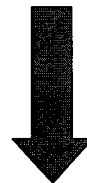
MMIC Receiver development and test



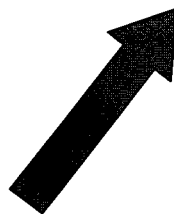
L-Band SAR Electronics miniaturization  
and prototype demonstration



AirSAR Technology Testbed



Future Radar Mission insertion



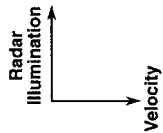
# AIRSAR/TOPSAR & SRTM



MT. FITTON 048-1 (D)

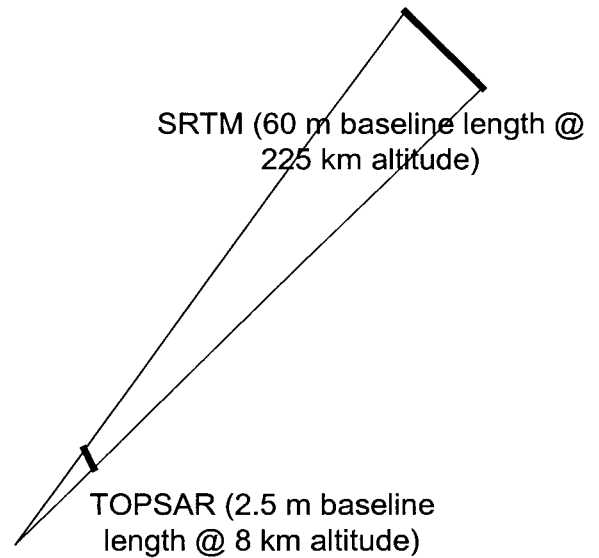
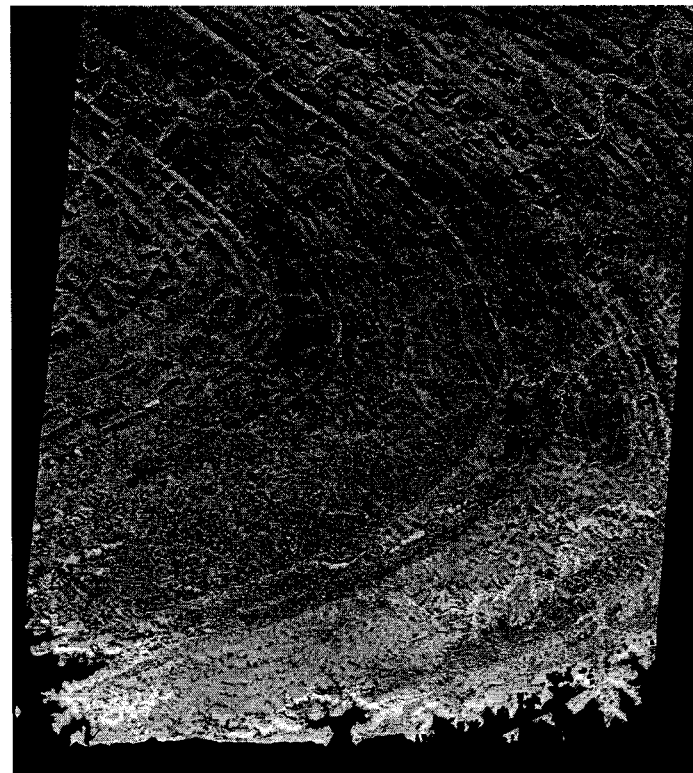
INTEGRATED AIRSAR PROCESSOR ( V. 6.10 )

405 800 Elevation (meters)  
Brightness: C-band VV Radar Cross-Section



Date Acquired:  
11-NOV-96  
Date Processed:  
30-MAR-98  
CCTID: TS0371  
Cntr lat: -30.34  
Cntr lon: 139.27  
Bandwidth: 40.00  
Cross-track:  
swath(km): 12.1  
samples in data: 1219  
reduction ratio: 1.0  
Along-track:  
swath(km): 10.9  
lines in data: 1097  
reduction ratio: 1.0

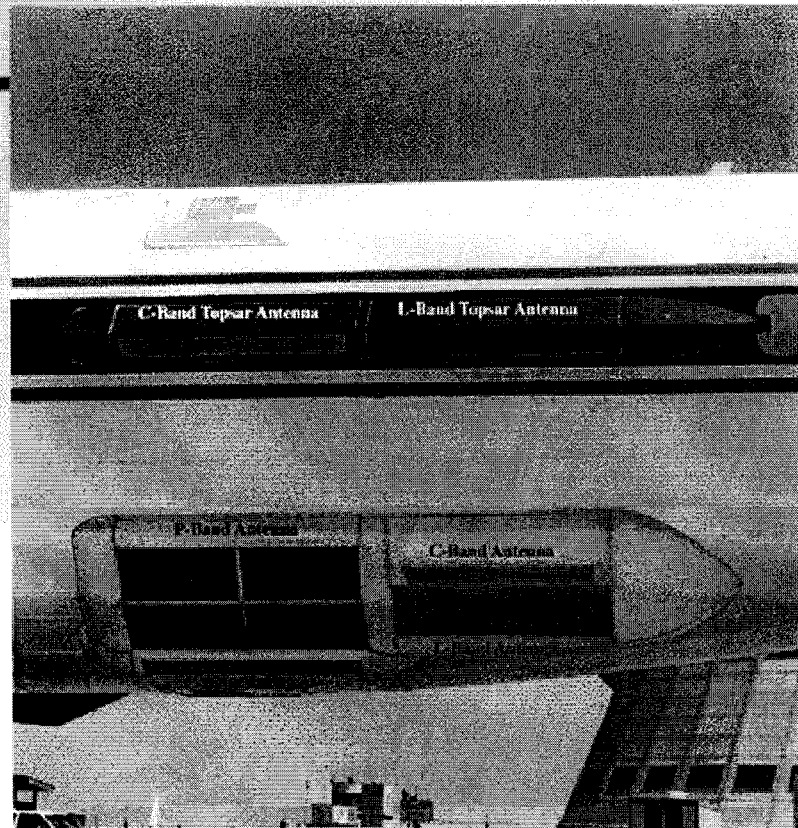
NORTH



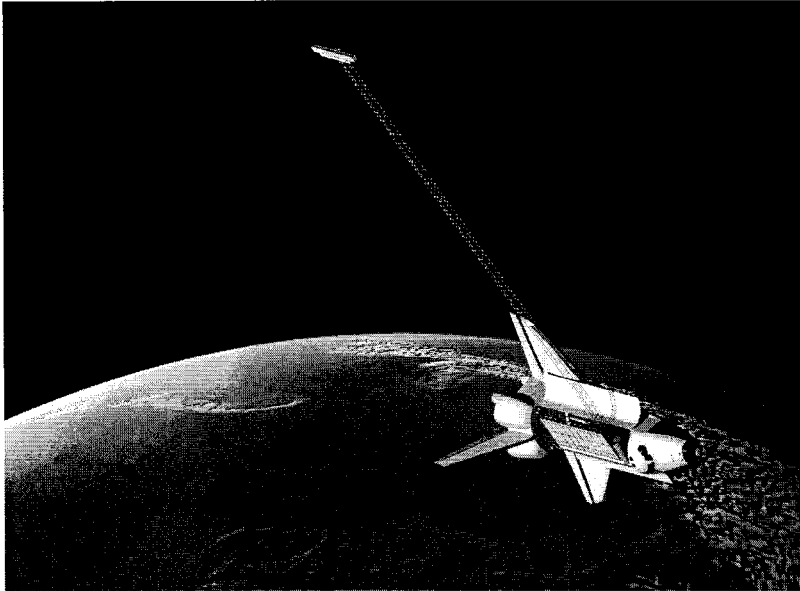
# AIRSAR/TOPSAR Antenna Configuration



## Current Antenna Configuration



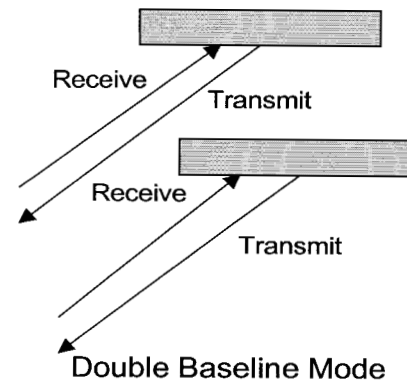
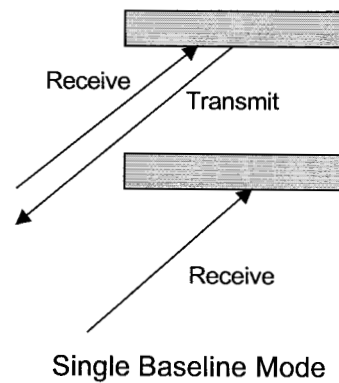
# SRTM (Shuttle Radar Topography Mission)



- *Partnership between NASA and NIMA (National Imagery and Mapping Agency)*
  - Science & military applications
- *X-band from German and Italian space agencies*

- DEM of 80% of the Earth's surface in a single 11 day shuttle flight
  - 60 degrees north and 56 degrees south latitude
  - 57 degrees inclination
- 225 km swath
- WGS84 ellipsoid datum
- Data products will be available to public through the EROS Data Center for the cost of reproduction.
- Details concerning the distribution of the data still being decided.
- Absolute accuracy
  - 20 m horizontal
  - 16 m vertical
- <http://www.jpl.nasa.gov/srtm>

# Scalar Interferometry Operation



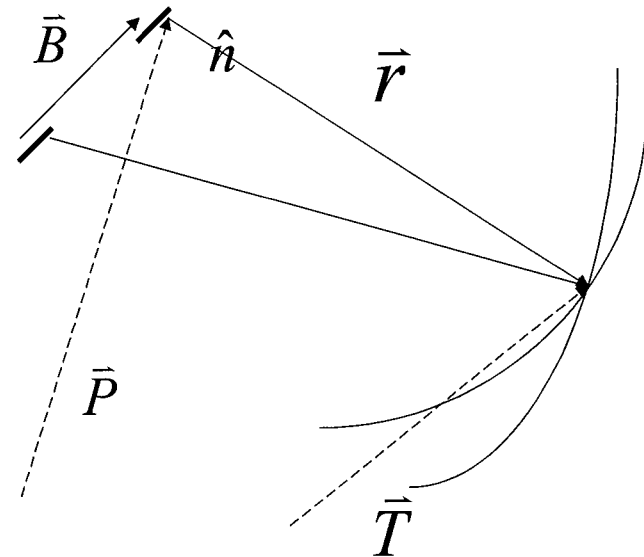
Interferometry

$$\begin{bmatrix} s_1 \\ s_2 \end{bmatrix} \begin{bmatrix} s_1^* & s_2^* \end{bmatrix} = \begin{bmatrix} s_1 s_1^* & s_1 s_2^* \\ s_1^* s_2 & s_2 s_2^* \end{bmatrix}$$

SAR Image  
Interferometric Phase  
Correlation Coefficient

# SRTM Calibration

- Ocean calibration
  - Parameter estimation using known heights
- Shuttle location & baseline vector
  - AODA (Attitude and Orbit Determination Avionics): GPS, Target tracker, Star tracker, Electronic distance measurement unit
- Relative channel phase
  - Caltone: closed loop optical link to the outboard injection point



$$\vec{T} = \vec{P} + \vec{r}$$

$$m \frac{2\pi}{\lambda} \hat{n} \cdot \vec{B} = \phi_t + \phi_r \quad \begin{array}{l} m=1 \text{ for SRTM} \\ m=2 \text{ for repeat pass} \end{array}$$

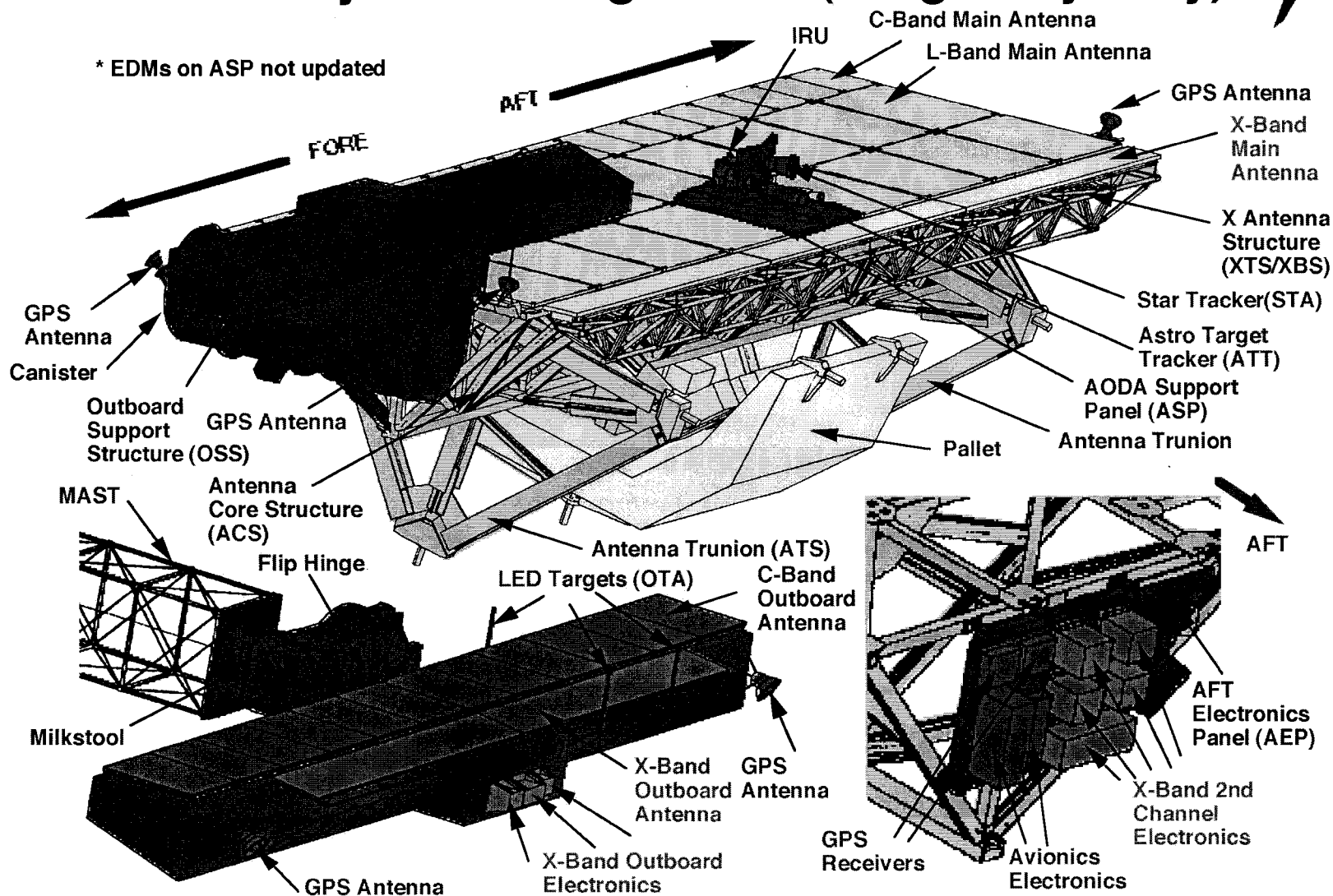
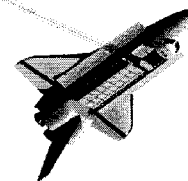
$$f_D = \frac{2\hat{n} \cdot \vec{v}}{\lambda}$$

$$|\hat{n}| = 1$$

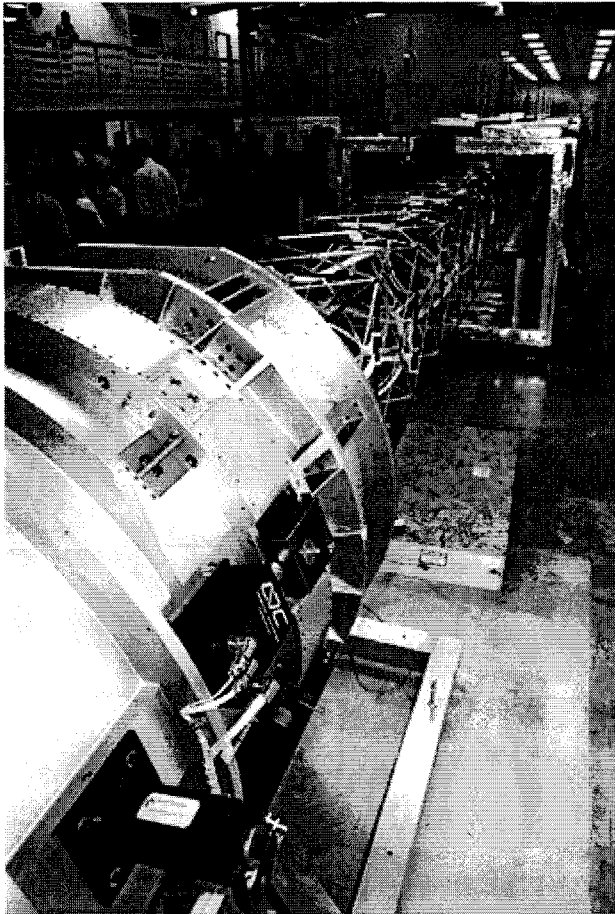


## SHUTTLE RADAR TOPOGRAPHY MISSION

# SRTM Payload Configuration (Cargo-Bay Only)



# SRTM Mast



- ADAM (Able Deployable Articulated Mast) built by the ACE-Able Engineering Company
- Mast is stored in a 1.4 x 3 m cylindrical canister for launch
- Mast is deployed and retracted by a motor driven nut within the mast canister
- Astronaut will initiate the mast deployment

# SRTM Mast



- 60 m mast
- Mast is a truss structure that consists of 87 cube-shaped sections, called bays
- Unique latches on the diagonal members of the truss allow the mechanism to deploy bay-by-bay out of the mast canister